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Ministry of the ENVIRONMENT

Insecticides Course

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MINISTRY OF THE ENVIRONMENT

PESTICIDES CONTROL SERVICE

INSECTICIDES COURSE

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MINISTRY OF THE ENVIRONMENT

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INSECTICIDES COURSE

HISTORY AND INTRODUCTION OF THE USE OF PESTICIDES

A pest can be defined as any agent which may act as a nuisance or can cause injury, damage and destruction. Within the scope of this course on pesticides, the pests to be dealt with will include insects, mites and destructive fungi. Not included at the present time are animal pests such as mice, rats, gophers, coyotes; birds such as magpies and pigeons; and weeds.

By definition, pesticide is any material designed to kill pests. Since pesticides are necessarily poisonous or corrosive, they can also be harmful to useful property, human beings, domestic animals and wildlife. During the past decade considerable publicity has been given to the harmful effects arising from the widespread use of pesticides. As with so many injurious agents, it is important to balance the useful properties against the potential dangers. For instance, as an analogy, the automobile and electric power can both be injurious or lethal if improperly used, but their useful properties are so tremendous that there is no suggestion of discarding them. By a system of education, research, standardization and legislation, the injurious properties are being brought under control.

It is the object of this course on pesticides to outline the basic principles involved in the use of insecticides and fungicides. Special attention is being given to the potential dangers of these materials, and it is hoped that the student will be familiarized with safe methods of handling, application and disposal. This introductory lesson will present certain background material, including historical landmarks, statistical information and a short discussion of the benefits resulting from the use of pesticides.

HISTORICAL BACKGROUND

Man has always been searching for the means to rid himself of pests. The most widely read of all historical documents, the Bible, frequently mentions the ravages of a variety of pests including lice, locust, rodents and other animals. As long ago as 900 B.C., Homer wrote of sulfur for fumigation and pest control. Pliny the Elder (23 to 79 A.D.) collected many of the early recommendations for pest control in his Natural History. These include many curious and ingenious concoctions, some based on folklore and superstition. However, due to illiteracy, poor communication, lack of basic knowledge and the absence of research, very little progress was made until the eighteenth century. As an example of the poor communication, it is now known that the Chinese used arsenic to control garden pests prior to 900 A.D., but the earliest record of this use in Europe dates back to only 1669. By the middle of the nineteenth century a variety of fairly effective pest controls were in common use, and these included the following:

animal and fish oils	petroleum oils
arsenic	pepper
brine	phosphorus
copper sulfate	soap solution
hellebore	soot
hot water	strychnine
lime	sulfur
lye	tar oils
mercuric chloride	turpentine
vegetable oils	whitewash

The nineteenth century Renaissance in scientific thought, particularly in chemistry and biochemistry, soon extended into the field of pest control. The modes of action of many poisons were elucidated, and the pesticidal activity of many coal tar derivatives were discovered before the turn of the century. Examples of the coal tar products include naphthalene and the dinitrocresols. Also at this time, the natural products pyrethrum, derris and nicotine came into general use as insecticides.

Developments in transportation led to the large scale commercial exploitation of profitable crops and it became increasingly important to protect them from damage and destruction by pests. In the field of medicine it was established that many communicable diseases were being spread by animals and insects. The need to develop safe and specific means of pest control rapidly became an economic necessity.

In the early part of the present century more active compounds containing arsenic, cyanide, chlorine, fluorine and sulfur were incorporated in pesticidal products. Most of these compounds were highly toxic to man, and the users soon became aware of the dangers of accidental ingestion or over-exposure. Unscrupulous manufacturers used untried or deadly poisons in formulations of doubtful value. The ignorant and often innocent users of these materials sometimes applied excesses under unsatisfactory conditions with disastrous consequences. In order to prevent adulteration and misbranding of agricultural pest control products, most European and North American countries had initiated some legislation before the First World War. In order to enforce legislation it was necessary to develop rapid and accurate methods of analysis for all pest control products.

In the U.S. the Association of Official Agricultural Chemists was born, and this Association has been most active in the development of the required standard method. Here in Canada the Federal Regulations include the Pest Control Products Act and sections under the Food and Drugs Act. In addition, many of the Provinces have instituted regulations such as the Pesticides Control Act in Manitoba and the Pesticides Act and Regulations here in Ontario. Both the Federal and the Ontario Regulations will be dealt with in detail in a separate lesson.

As in so many other fields, the two world wars added considerable stimulus to research and development of pest control products. The search for more effective and lethal poison gases in the First World War led to the development of most of the major fumigants in use today. The research by the Germans on the organophosphorus 'nerve gases' for the Second World War led to the development of the highly effective modern organophosphorus insecticides.

Since 1940 the intense interest which has been aroused in the organochlorine insecticides is almost entirely attributable to the fantastic performance of DDT against an array of insect pests; coupled with its performance as a reasonable safe residual control agent capable of killing unsprayed insects which crawl over the persisting residues left on treated surfaces. DDT was a classical example of an organic chemical first synthesized as long ago as 1874, but its insecticidal properties were not discovered until 1939 by Dr. Paul Muller working in Switzerland. The medical significance of DDT led to the presentation of the Nobel Prize in medicine to Dr. Muller. The most striking example of the value of DDT was the control of the louse-borne typhus outbreak in Naples during 1944. In January of that year, over one million persons in Naples were dusted with a DDT formulation, and within three weeks the outbreak was under control - an event unparalleled in medical history.

As a result of the modern 'explosion' in knowledge and manufacturing methods, the farmers, horticulturists, biologists and public health authorities are left with a legacy of several hundred pest control chemicals which may include any of the following:

- defoliants
- disinfectants
- fumigants
- fungicides
- growth regulators
- insecticides and acaricides
- rodenticides
- seed disinfectants
- selective herbicides
- soil conditioners
- soil fumigants
- weed killers

It is hoped that this lesson on pesticides will enable the student to understand the nature of these materials, and by being cautious and selective in the materials he uses the benefit will be reaped by the whole community.

MODERN DEVELOPMENT OF PESTICIDES

Like the penicillin antibiotics, DDT did not become the golden 'cure-all' that was hoped for. Unfortunately many insects developed resistant strains which multiplied and defied further control of DDT. In some cases the use of DDT, while controlling a particular species of insect, led to the flourishing of other species not affected by the chemical. Other insecticides were urgently required to supplement the control effected by DDT. Thousands of compounds structurally related to DDT have been synthesized and evaluated as insecticides, but only a few have survived to commercial production. Similar problems arise in relation to herbicides and fungicides, but with these materials there are added complications. In the control of certain weeds or fungi it is often necessary to destroy the offending growth without harming the productive crop. This has led to considerable research and expenditure in the development of selective herbicides and fungicides.

Though the days of the 'accidental' discovery are not over, the development of new and more effective pest control chemicals has become a considerable expenditure by many major organizations. Each project becomes a masterpiece of teamwork between a number of highly trained specialists including chemists, biochemists and agriculturists, together with an army of ancilliary technicians and administrative workers.

The requirements of the Canada Pest Control Products Act and the relevant sections of the Food and Drug Act are so rigorous that all new pest control products must be thoroughly investigated before they can be marketed. When so many persons, so much time and so much money are involved, it is highly unlikely that some ineffectual or unusually hazardous product will slip through the stages of development. Providing that a pest control is applied sensibly according to the manufacturer's directions, and against the specified pest, there should be no possibility of a hazard to persons or property.

METHODS OF PEST CONTROL

Pest control broadly includes all agents which will make life difficult for pests, either by killing them or by preventing their spread and multiplication over the area in question. Such control may be attempted or can occur in a number of ways, which may include the following:

(a) Natural control
Climatic factors (e.g. temperature and humidity) topographic features (barriers such as rivers, high land, etc.) predators (birds, animals, etc.) diseases (virus, fungus and bacterial infections).

(b) Applied control
Biological (sterilization or introduction of diseases), chemical (application of pesticides or repellents), cultural (crop rotation, introduction of hardy crops) mechanical and physical (hand destruction, ploughing, etc.) legal measures (restriction of cattle or crop movement, quarantine, etc.)

Evidently the application of pesticides represents only one of a number of control measures. Before embarking on the widespread use of toxic and expensive pesticides, each situation should be examined for the possibility of alternative control measures. Expert advice should be sought, if there is any doubt.

The use of several control methods, including natural and applied, is commonly known as integrated control. Some areas in which integrated control measures have been particularly successful either in eradicating or in minimizing the effect of certain pests include:

Pest Controlled	Area
African mosquito	Brazil and Egypt
Brown tail moth	New Brunswick and Nova Scotia
Cattle tick	U.S.A.
Citrus whitefly	California
Codling moth	Western Australia
Colorado potato beetle	England
Date palm scale	Arizona, California, Texas
Khapra beetle	Southwest U.S.A., Mexico
Mediterranean fruit fly	Florida
Northern cattle grub	Clare Island, Ireland
Screw-worm	Curacao
Rat	Ontario

Most of the control measures mentioned above are well known and will not be discussed any further. In recent times much publicity has been given to the biological control measures. This kind of control has been highly specific and very successful in certain instances, but there are certain drawbacks which are worthy of mentioning.

Radiation sterilization - This method proved to be highly successful in eradicating the screw-worm in Florida. Thousands of male flies were artificially reared and sterilized by a high dose of gamma radiation. These males were then released and mated normally with the female flies. Eggs were laid normally but never hatched, and multiplication of the species ceased. This method requires specific means of attracting the male insect, followed by the controlled use of a radiation source and expensive equipment. Considerable research must be done to find the correct dosage. It is not a method which can be applied by a farmer or group of farmers on their own. Radiation sterilization can only be used in specific instances and is not ideal. For example, the male boll weevil cannot take the 5,000 roentgen radiation dose required for sterilization, and were unable to mate after radiation.

Chemosterilants - Some success has been reported with chemical sterilants used as food to achieve the same effect as radiation. The sterilants are highly specific for the species in question and considerable research remains to be done.

Attractants - The Mediterranean fruit fly was controlled in Florida with the help of an attractant which gave information on the numbers and locations of the pest, thereby helping the pesticide applicators to know when, where and how much of an insecticide to use. Attractants may be used to lure the insects to a given location where they can be effectively exterminated without contaminating large areas or crops with insecticides. Attractants which have been used include sex lures, food lures and oviposition lures. Here again, these attractants are highly specific for the species in question. The chemical analysis and synthesis of these compounds requires much painstaking laboratory work, and progress is very slow.

Antifeeding compounds - Some success has been achieved in the production of these compounds, which will prevent chewing insects from feeding on a crop. Although research on these compounds is still in the early stages the outlook is promising. An offshoot from this is the development of insect-resistant strains of plants, for example, the sawfly-resistant wheat now widely used in Canada.

BENEFITS FROM PESTICIDES

In these days of agricultural plenty (here in North America) and the highest standard of living in the world, when we are assured of the safest and most wholesome food supply ever known, we find it difficult to recall that not long ago our forefathers often suffered famine and disease caused by pests.

It is not possible, in the short space of this lesson, to do justice to the enormous benefits that man has reached through the use of pesticides. A few highlights will be given to indicate the general trend.

Millions of lives have already been saved through the control of insect-borne diseases. Some typical examples of these diseases are shown on page 8.

There are several spectacular examples of disease control by insecticides. These include the suppression of the louse-carried typhus outbreak in Naples mentioned earlier, and the elimination of malaria in the United States. Up to the Second World War, malaria was still a scourge in Italy and Greece. Concerted use of DDT and other control measures resulted in a drop in malaria death rate from 4,000 in 1944 to sporadic incidence at present. Similar success has been achieved in several countries with many of the diseases shown on page 8, due mainly to effective public health measures, together with vector control.

Disease	Vector *	Remarks
African Sleeping sickness	Tse-Tse fly	-
Anthrax	Horse fly	All mammals affected
Bubonic plague	Rat flea	Rodents also affected
Dysentry	Flies, lice, etc.	-
Epidemic typhus	Lice	-
Equine encephalitis	Mosquitoes	-
Malaria	Anopheles mosquito	Birds also affected
Onchocerciasis	Black fly	-
Rocky Mountain spotted fever	Ticks	Rodents also affected
Trypanosomiasis	Flies	Many animals affected
Tularemia	Flies, fleas, lice, ticks	Rodents & Birds affected
Yellowfever	Mosquitoes	Animals affected

* A disease vector may be defined as an intermediate carrier of pathogenic micro-organisms from one host to another.

Large numbers of people are still dying in Africa, Asia and South America from vector-borne diseases. The world Health Organization is spending many millions of dollars annually on insecticide application and on research into more effective means of vector control. It has been estimated that a disease-free Africa could accommodate two billion people on a reasonable economic level, rather than the present 170 million.

It has been calculated that in North America our food supply would be cut by at least 30% within two years if chemicals were eliminated from food production, and we would once again have to accept worms in fruit, caterpillars and slugs in lettuce and grubs in our peas and beans.

In the 'good old days' the farmers planted their seeds according to the formula 'one for the moles, one for the crow, one for the blight and two to grow'. Such formula is quite intolerable in these days when every farm worker produces the necessary food and fibre for twenty-five persons. (In 1920 each farm worker supported only eight persons). With the predicted explosion in world population, even more efficient methods of food production are necessary and elimination of losses due to pests is imperative.

The great improvement is not entirely due to insecticides, and must be partially attributed to the use of fertilizers, herbicides, fungicides and antibiotics, as well as improved management techniques. It is not possible to separate the influence of pesticides, but there is no doubt that these have played their part. For example, the improvement in the quality of meat has been due to many factors including better management, improved feeds, suppression of disease by antibiotics and vector control, better control of ticks and cattle grubs, and improved breeding stock.

Treatment of consumer goods and timber products with insecticides and fungicides is having a great impact on our living comforts. We no longer expect to find moth holes in our woolen garments, nor do we expect our furniture to be riddled with woodworm. These results are achieved partly by preventive treatment and partly by our own persistence in keeping the pests outside the home with the aid of aerosol sprays, impregnated polishes and other mysterious charms. It is impossible to estimate the savings accomplished by these means relative to the days before their use.

NATURE AND USE OF INSECTICIDES

ELEMENTARY ENTOMOLOGY

Insects are the most abundant and widespread of the land animals and can be found in many different kinds of habitats. They feed on a great variety of materials, including plants, stored products, the blood of man and other animals including insects, dung, and dead plant material. Insects are characterized by a chitinous body covering that protects their internal organs against injury and loss of moisture. They are generally small, some so small that they cannot be seen, and they multiply rapidly. Many can fly and this helps them to find food readily. Some go through four distinct stages in their life cycle; the egg, larvae, pupa and adult. The egg and pupae are the inactive stages and they can withstand extreme unfavourable seasonal changes. The active stages, which are the larvae and adults, can feed on entirely different foods. (Some insects go through only three stages; the egg, the nymph and the adult). All of these characters have been responsible for the success of insects in establishing themselves in a variety of habitats and adapting to changing conditions.

One of the greatest problems facing someone involved in insect pest control is that of the proper identification of a suspected insect pest. Proper identification involves some knowledge of the naming of animals. All known organisms have been assigned scientific names to clearly distinguish them from other similar organisms. The unit of classification is the species (both singular and plural) and is used to designate a group of organisms which possess similar characteristics such as shape, life history, habits, etc., and which interbreed and produce fertile offspring.

A group of species is placed in a genus (plural: genera) so that any known organism possesses both a generic and a specific name. This is the binomial system of classification of plants and animals. For example, the common housefly is named *Musca domestica*; the first name is the generic name and the second is the specific name.

Genera are then placed in the next higher category: Family. *Musca domestica* for instance, belongs to the family Muscidae.

The next category is the Order and for the housefly this is the Diptera. With few exceptions, (such as suborders of some insect orders), the orders are grouped next into Classes (insects are placed in the Class

Insecta). And finally Classes themselves are grouped into Phyla which are the main divisions of the animal kingdoms. Insects belong to the phylum Arthropods.

In some cases, it is only necessary to know the general grouping, that is, the family or the order to which the insect belongs. For instance, while there are over one hundred different kinds of aphids in Ontario, it is enough in most cases to know that many of them are found only on specific plants or groups of plants, and that the great majority of them are not pests. This principle applies to many other insects as well. But anyone involved in pest control should be able to recognize the more common forms of insects associated with agricultural and garden crops; in stored grains, and other stored products; parasitic on man and his domestic animals; and the beneficial insects such as ladybird beetles, ground beetles, honey bees, bumblebee, and others. This knowledge can only be attained by the continued practice of trying to identify insects seen under different situations. There are certain circumstances where absolute identification is necessary, such as for example, insects caught near the source of crop damage but not actually seen feeding. Under these circumstances, specimens should be collected and sent to any of the various authorities throughout the province for proper identification.

Before a study can be made of the different groups of insects found in Ontario, some knowledge of external morphology is needed. Insects are characterized by having six legs in the adult stage as well as in the young nymphal stages of many forms. The body consists of three regions, that is, the head, thorax and abdomen.

The head bears eyes, one pair of antennae (which often serve to distinguish between different groups of insects) and the mouth-parts. There are many different kinds of mouthparts of insects that are important in helping to establish identification. The main types of mouthparts are as follows:

1. Chewing - found in cockroaches, grasshoppers, silverfish, crickets, beetles, etc.

2. Piercing-sucking - found in biting flies, mosquitoes, plant bugs, aphids.

3. Rasping-sucking - found only in thrips and minute insects which live on plants.

4. Sponging or Lapping - found in houseflies, as well as other non-biting flies.

5. Siphoning - found in moths and butterflies.

6. Chewing-lapping - found in honey bees, bumble-bees.

The thorax of insects consists of three segments with a pair of legs on each segment. That part of the leg in contact with the ground is called the tarsus and consists of different numbers of segments or articles which are useful in identifying the insect. The second and third thoracic segments bear wings or modifications of wings. For instance, in flies the third thoracic segment bears a pair of knobbed structures called halteres which are modified wings, while in beetles the wings of the second thoracic segment have become modified into wing covers of elytra.

The abdomen has up to nine distinguishable segments and the most conspicuous structure found in many insects of the abdomen is the ovipositor, the organ which deposits the eggs. This organ is usually found near the posterior, and behind and above it are the cerci, which are paired antenna-like projections.

Insects vary in type of development, as follows:

Ametabolous - The young resemble the adults though they are much smaller when hatched from the egg. This is the case with snow fleas or collembola.

Hemimetabolous - The young of this group resemble the adults except for the gradual development of wings throughout the growing stages. The immature forms are called nymphs and they usually eat the same food and have similar habits as the adult insects. Cockroaches, grasshoppers, bedbugs, etc., are found in this group.

Holometabolous - The young of this group differ markedly from the adults, in appearance and generally in food habits. The young of bees and wasps, butter-flies and moths, beetles, flies, etc., are called larvae. These forms pass through a distinct resting stage called the pupa in which they transform into adults.

CLASSES OF INSECTICIDES

Insecticides have been classified according to how the poison is absorbed by the pest species.

Contact poisons are those that kill insects when they come in contact with the poison and a toxic dose is absorbed through the cuticle.

Stomach poisons are those compounds that are more effective when the insect ingests a toxic dose.

Fumigants refer to the highly volatile compounds and the toxicant is absorbed as a vapour through the cuticle and respiratory spiracles.

Since the advent of the synthetic organic compounds, following 1945, it became more convenient to classify most insecticides according to similarities in chemical structure. The toxic action of these compounds is usually a combination of effects and it is difficult to classify them according to their route of absorption.

Chlorinated Hydrocarbon Insecticides

These compounds differ widely in chemical structure and activity. They are well known because of their relatively low cost, and their effectiveness in insect control. In general, they are persistent compounds that remain for a considerable period on treated plants and in soils and are readily stored in animal body fat. Because of their persistence and stability they are effectively used as soil insecticides, but residues of these compounds on plants have caused problems with contamination of animal and human food. These compounds can accumulate in animals or humans through storage in the body fat even when trace amounts are in the feed. Contamination of milk and other dairy produce has occurred through the use of these materials and, as a consequence, restrictions have been placed on their use.

Organophosphate Insecticides

These are a large group of compounds that range from some of the most toxic to some of the safest insecticides in use today. Unlike the chlorinated hydrocarbons, these compounds are not persistent - they break down quite rapidly in the animal body and are not stored in animal tissue or fat. However, successive exposure to small amounts can lead to poisoning sysptoms in man. In general, these compounds are unstable in alkaline media, making them unsatisfactory as soil insecticides. Some are plant systemics that are readily translocated within plant tissues; others are animal systemics that contribute extensively to the control of livestock endo- and ecto- parasites. Because of their rapid breakdown there is less danger of residue contamination.

Miscellaneous Compounds

(a) The Carbamates are a relatively new group of compounds with most of them still in the development stage. These are similar in action to the organophosphorus insecticides but are, in general, a safer group with possibly better residual properties. They are more selective in their toxicity to insects than either the chlorinated hydrocarbons or organophosphates.

(b) The Botanicals are plant derivatives or extracts that have a low persistency but are good contact and knockdown insecticides. These are generally used in combination with synergists, which are compounds that serve to enhance the insecticidal properties of the botanical. These compounds are being replaced by the less costly organophosphates.

(c) The Inorganic Insecticides are in limited use today. Most of these contain arsenic in various forms and are effective stomach poisons, but they are being replaced by the more efficient synthetic compounds.

PRECAUTIONS IN HANDLING INSECTICIDES

Insecticides are poisons developed to kill insects and can be extremely hazardous. Humans and livestock may be accidentally poisoned by swallowing the insecticide, by eating insecticide-contaminated food, or by prolonged exposure to dusts and sprays. Continued exposure to small quantities may not cause visible symptoms but can damage the liver and other vital organs, and can accumulate in the fat and milk of animals.

If blurred vision, tightness of chest or nausea are noticeable after exposure to insecticides, call a physician at once or take the victim to a hospital immediately. Be certain what insecticide was used. Take the label of the container to the doctor - the antidote might be listed on it.

All pesticide applicators should acquaint themselves with the following precautions when applying, mixing, or otherwise using insecticides:

(a) Read the label on the container: The information may save your life and prevent accidents. The label will properly identify the toxicant. It will tell you how to handle the material and what to do in case of an accident. Follow the rates of application as stated therein and strictly observe the cautions with regard to the correct pre-harvest intervals and use of treated crops.

(b) Wear protective clothing: Coveralls, rubber gloves, goggles and rubber boots. If concentrates are being handled, special care should be exercised. Gas-tight face masks should be worn while handling extremely volatile materials. Never use a dust mask while applying fumigants. A full-face, respirator-type gas mask should be worn and filters should be changed frequently. Suitable spray and dust-proof masks should be used when dusting or spraying with extremely toxic materials.

(c) Avoid spilling: If pesticides are spilled on the skin, wash immediately with soap and water. Change contaminated clothing as soon as possible and wash them before re-use.

(d) Avoid continued exposure: While spraying and dusting, prolonged exposure should be avoided, sprays and dusts should not be inhaled, smoking (especially hand-rolled cigarettes should be avoided, and all exposed parts of the body should be washed immediately after the application is completed.

(e) Avoid contamination: Do not apply insecticides at rates higher than those specified. Do not contaminate feed for livestock or crops that might become feed or foodstuffs. Do not contaminate water sources when filling or emptying sprayers or while spraying.

(f) Take good care of equipment: Sprayers should be in good working order at all times, to avoid leaks and clogging while in operation. Equipment that has been used for herbicide application should not be used for insecticides because traces of herbicide are difficult to eliminate through ordinary cleaning and may cause damage to susceptible crops. All spraying equipment should be thoroughly cleaned after each use.

(g) Store pesticides with care: Keep all pesticides in their original containers with proper labels. Store them in safe places away from food or where food is handled. Keep out of the reach of small children, pets, irresponsible persons.

(h) Disposal of pesticides and containers: Destroy metal containers with a pick and break glass containers. Bury them in areas where they will not contaminate water sources. Burn paper containers and avoid smoke from such fires. Pour unwanted pesticides in a hole in a designated waste area. Lime may be used to help to break down organophosphate compounds. Never re-use empty containers. See section on disposal of pesticides in Regulations.

CHOICE OF INSECTICIDE

Many factors determine the choice of the best insecticide for each purpose. Some of the most effective insecticides cannot be used because they damage plants, are too dangerous to handle, or leave dangerous residues. All of the many insecticides are not readily available. Cost of application and suitability of formulation are also factors.

We cannot list the best insecticides for each insect on each crop or animal. New insecticides are being constantly developed. New methods of chemical analysis to detect residues and further research may soon remove any insecticide from the recommended list. An insecticide may also become unsuitable if insect pests become resistant to it.

WHEN TO APPLY

The decision as to when to apply an insecticide requires a thorough knowledge of the insect to be controlled and of the insecticide to be used. In many cases the time for control may have already passed and the use of an insecticide may result only in a waste of time and money. For example, the stink bug may require control on wheat, that is in the early boot stage, but after the crop is well headed-out little further damage will occur and treatment then is wasted. It is equally important to realize that the need for treatment may never occur in some cases. An example of this is the sugar-beet root aphid, which is readily controlled by its parasites and predators. An insecticide may only create a problem by killing off the beneficial parasites and predators to give the pest insect a chance to increase.

Time of Day - On hot, calm days spraying from aircraft is better done in the early morning or evening as convection currents during midday move upward carrying much of the spray with them. On seed crops that are insect-pollinated and on bee pastures, the spraying should be done late in the day when few bees are present in the field.

Weather - High winds cause drift that may contaminate nearby fields, reduce the amount of insecticide that hits the target area, and increase the danger of poisoning to the spray operator. Ground spraying should be done at right angles to the direction of the wind. Certain insecticides should not be applied at low temperatures because they are not effective then. Spraying is best done when the wind speed is less than 5 m.p.h.

Date of Treatment - Most insecticides are restricted as to the length of period between the date of application and the date of harvest or slaughter. It is very important that this wait period be known for each insecticide used and that the restrictions be obeyed. If not, the crop or animal may be contaminated by illegal residues of insecticide. The crop may then be seized and destroyed. Instructions concerning this period are found on the label of the insecticide container.

For certain insects, notably warble grubs on cattle, specific dates of application are given and should be followed.

FORMULATIONS

Most insecticides are mixed or formulated with various additives before they are sold. These formulations are then diluted with water, oil, or dusts before they can be properly used. Insecticides are produced by the manufacturer as technical chemicals, which are usually too poisonous to be handled by untrained workers. A recent method of control of grasshoppers, however, is the use of technical insecticide applied without dilution from aircraft. The common formulations of insecticides are discussed below:

1. Emulsifiable concentrates consist of an insecticide dissolved in a solvent, usually a petroleum oil, to which an emulsifying agent has been added. When diluted with water the emulsifier allows the insecticide and its solvent to remain suspended as fine droplets. The mixture is then applied as a spray. At the proper concentrations the spray can be safely used on both plants and animals. Care should be taken to store the concentrate at proper temperatures and to see that the emulsion does not settle out during spraying.

2. Insecticidal dusts consist of insecticide diluted with a mixture of finely ground materials such as talc and various clays to form a product that does not become lumpy when stored. Unless the applicator has suitable equipment for mixing he should buy the dusts ready for use. They can be used on almost any surface without harm to it and have the advantage of good penetration into crevices and around irregular objects. Drift problems are a disadvantage. When dusts become moistened, however, they may cake and become ineffective. Dusts are used for certain livestock insects, for household insects, and a few insects on plants. Granules consist of insecticide impregnated on larger particles or pellets. Granules do not give as good coverage as do the dusts but they can be broadcast from aircraft and ground machines and are less affected by winds. Insecticides can also be impregnated in fertilizers to control insects in the soil.

3. Oil concentrates and solutions consist of insecticide dissolved in a solvent such as kerosene then diluted in a base oil. They are toxic to plants and may be fire hazards. Generally, they kill insects more rapidly than do other formulations. They are applied by spraying, dipping, or impregnating. These formulations are used in the control of wood-infesting insects, or as long-lasting sprays in buildings

to control certain household insects. The solutions should be stored in a warm but not a hot location. Care should be taken when using on wallpaper, some synthetic fibres, and floor tiles of various types that may be damaged or stained by the oil.

4. <u>Wettable powders</u> are made of inert powder impregnated with insecticide and mixed with a wetting agent. The wetting agent keeps the powder in suspension when mixed in water. The suspension must be agitated to prevent the powder from settling out. It is abrasive to spray equipment and readily plugs strainers and nozzles. Wettable powders are safer to plants than are emulsions or solutions, and are useful on surfaces indoors where the appearance of the powder is not important. In Ontario they are recommended for livestock insects and for insects that attack crops. Wettable powders are safer to store and handle than emulsifiable concentrates.

5. <u>Soluble powders</u> are soluble powders impregnated with insecticides. When diluted with water the insecticide remains in solution. These are becoming more common.

6. <u>Aerosols</u> are extremely fine droplets of insecticide solution suspended in air. The droplet is less than 50 microns in diameter (1 micron = 1/1000 millimetre). Although mist-blowers may produce aerosols, most aerosol generators use heat or liquified air. The finest aerosols are used as space sprays inside buildings, or fogs are used outdoors to control flies and mosquitoes. Aerosols are most suitable for control of flying and crawling insects present in the area at time of application.

7. Insecticides are also impregnated in cords, bands, and discs for control of flies, and combined with bran and other materials as baits for ants, flies, slugs, and cutworms. They may also be dispersed as gases to fumigate for insects in the house, in storage, and in greenhouses.

STAGE OF DEVELOPMENT OF INSECT

Insects are usually most vulnerable to the effect of insecticide when they are immature, e.g. larvae or nymphs. They are less mobile then and also are usually killed by less poison. The amount of damage they might cause is reduced. Control during the adult stage may be required for insects such as house flies, mosquitoes, Colorado potato beetle, weevils, and some other insects. In other cases however, adult control is of doubtful value. Control of adults has little effect on future outbreaks except where a particular insect is limited to a restricted area as in the case of stored product insects. It is hoped, however, that in the future the control of adult insects will become more useful with improvements in the use of attractants and sterilants. Adult control by these methods could eliminate or reduce many problems with residues that we have today.

PREVENTIVE TREATMENT

Preventative treatments are often the only satisfactory means of controlling concealed insects that bore in plants, mine in leaves, feed inside animals, and feed on the roots of plants. In these cases control may often be obtained with systemic insecticides applied before the insect pest appears or damage occurs. Examples of these insects are aphids that cause galls on elm leaves, leaf miners in birch and lilac, and warble grubs in cattle. Seed treatment is the best control for wireworms, certain root maggots, and for flea beetles on crops such as rapeseed. Moth-proofing is a good method of preventing damage from clothes moths.

Major disadvantage of preventative treatment is that it may be continued even after it is unnecessary or done before it becomes necessary. Wireworm control is an example of this.

NATURE AND USE OF FUNGICIDES

WHAT ARE FUNGI?

Fungi are living organisms belonging to the plant kingdom. They are referred to as lower plants. Unlike green plants they lack chlorophyl and being incapable of manufacturing their own food they live off dead or living plant or animal matter. Those obtaining food from non-living materials are called saprophytes. Others obtain their food entirely or partly from living material and are, therefore, called parasites. If the material on which they feed is a living plant the resulting situation is regarded as a plant disease, and the fungus is a pathogen.

As in higher plants there are many thousands of different kinds of fungi. Each has its particular size, shape, color and growth characteristics, but more important, parasitic fungi usually exhibit a distinct specificity for the plants that they can infect and parasitize. For example, a fungus causing a leaf disease known as scald can attack only barley of our cereal crops. Another one causing a root rot can affect only barley and wheat. The number of different kinds of plants that a particular fungus can parasitize is known as its host range, and in most cases the host range is fairly narrow.

To create order out of chaos, each fungus species is carefully described and given a Latin name. The Latin name consists of two words, the genus and the species, the former designating the broader group to which the fungus belongs and the latter is its specific group. Thus the above mentioned fungus, causing barley leaf scald, is called *Rhynchosporium secalis*, and the one causing root rot is named *Bipolaris sorokiniana*. There are approximately 100,000 species of fungi, and of these about 30,000 can cause plant diseases.

A parasitic or a saprophytic fungus is but one of the countless individuals in the living world. To maintain its position it must live and grow, reproduce, be scattered about and, under certain circumstances, survive periods during which the environment is relatively unfavourable to it.

Structurally fungi are mostly very tiny but very complex. Most of them are composed of microscopic filaments which may be colorless or variously colored. Considered individually the filaments are called hyphae (singular: hypha). In aggregate they are spoken as a mycelium. Hyphae may be organized in various ways to give them greater ability to survive adverse conditions. At times the hyphae join in parallel to form long, rope-like strands, or rhizomorphs, which aid in advancing through the soil. At other times the hyphae may form hard, compact, rounded masses analogous to a tightly compressed ball or yard, called sclerotia (singular: sclerotium), which serve as resting bodies to carry the fungus through hot, cold, or dry periods.

While fungi can reproduce by means of broken-off bits of mycelium, their common method of reproduction is by spores. These are one - or several - celled, microscopic seed-like bodies varying greatly in size, shape, color, thickness and structure of the spore wall. They may be produced randomly over the mycelium but often are enclosed in special receptacles called fruiting bodies.

Spores are usually adapted for distribution by wind, but some move about by swimming, others have no special means of spread and usually remain imbedded in the plant or in the soil. Because of their remote chance of reaching a plant which they can parasitize, spores are usually produced in astonishing abundance. Total numbers from a single diseased plant usually must be estimated in millions, billions, even trillions.

When a spore reaches a plant which it can parasitize it must enter it before infection and disease development can occur. Under favourable temperature and moisture conditions the spores start to grow by sending out germ tubes. These are much like any hypha. After growing for some distance over the plant surface they penetrate the plant cell walls and enter the tissue inside. Here the fungus establishes a relationship with the plant whereby it can obtain food. Besides robbing the plant of its nutrients, these parasitic fungi may inject toxins or hormones into the plant. The various enzymes produced by the fungus may disintegrate plant tissue. In any event, the parasitized plant is damaged and exhibits outward effects (symptoms) of the disease.

Symptoms differ, depending on the species of the fungus attacking the plant, but are usually fairly constant for a particular fungus parasitizing a particular plant. Symptoms are therefore useful for diagnosing the cause of the disease. Some of the common symptoms are lesions (areas of dead cells); rots; galls; stunting; distortion; color change or replacement of plant parts by the pathogen.

Fungi differ physiologically, depending on the species to which they belong. Because of these physiologic differences and their morphologic features, different chemicals may be required to control them. This explains partly why there is such a great variety of fungicides on the market.

WHAT ARE FUNGICIDES?

Chemicals used to control fungus diseases are called fungicides, a word derived from the Latin, fungus, a microscopic plant, and caedo, "I kill".

Originally the term was restricted to any substance applied to higher living plants in active growth to kill parasitic fungi or prevent the development of fungus diseases without seriously injuring the host plant. The meaning has been further broadened and as currently used, denotes any substance or mixture of substance used, for controlling fungi present in any environment. Thus, chemicals used to control fungi in or on the following materials and locations are properly called fungicides: growing plants; harvested fruits and vegetables; seed; soil; wood; storage facilities; clothing and equipment.

In agriculture, fungicides are mostly used to prevent infection because once the fungus has caused any damage to the part attacked, little is to be gained by killing the pathogen. To do so will not repair the damage already done, although it may prevent the further spread of the fungus.

CLASSIFICATION OF FUNGICIDES

Fungicides can be conveniently divided into three groups according to their action.

Protective fungicides are applied as foliage sprays or dusts, as seed or soil treatments, or as clothing and equipment treatment to keep damage-causing fungi from establishing themselves on these materials. Their greatest use in agriculture is, of course, in the protection of growing plants. In other words, protective fungicides are designed to be present at the infection site in advance of the pathogenic fungus in order to prevent infection.

Protective fungicides, to be successful, must have certain characteristics. An acceptable one is usually a well-balanced combination of active ingredients with high toxicity to fungi and none or very low toxicity to plants, a suitable diluent or solvent with a wetting agent to ensure uniform spread, a sticker to provide tenacity or adhesiveness; and in some cases a dye to identify treated material.

Eradicant fungicides are applied with the intent of checking fungi that are already on or in the material in question. In agriculture, these fungicides are most effective in destroying spores and mycelium that adhere to the surface of plant material, e.g. seed or nursery stock. Such material is regarded as being infested and the fungicide in this case could also be referred to as a disinfestant.

Eradicant fungicides have limited use in destroying fungi that have already penetrated and infected the plant material. If used in this situation they are referred to as disinfectants. They are often damaging when used on green foliage.

Chemotherapeutants are chemicals absorbed and distributed within the plant to control certain diseases. Very few chemicals which are now available, work in this way, but chemotherapy is currently a very promising field of research. Antibiotics may play the major role in this type of disease control.

In the past few years a great many new fungicides have been introduced. The chemical names (called active ingredients) of the new fungicides printed on many package labels, are difficult to remember or pronounce. Fungicides are marketed under a bewildering assortment of trade names. To relieve confusion, a set of common names (e.g. Captan, Ferbam) has been officially adopted and is being increasingly used on package labels in place of the more complicated chemical names.

MODE OF ACTION OF SOME FUNGICIDES

The mode of action of fungicides (i.e. how they actually kill or inhibit pathogenic fungi) must be considered at two possible sites. These are: (1) the cell wall of the fungus, and (2) the inside or protaplasm of the cell.

Cell walls of fungi are complex and variable structures. Among substances reported to make up the cell walls of fungi are chitin, cellulose, pectin, lignin, proteins and lipids. Although all of these materials are not necessarily present in the wall of any particular fungus, lipids, protein and chitin are generally present.

Several types of fungicides, e.g. copper and carbamates, cause leakage of materials from the cells. Loss of ability to maintain material concentrated within the cell is sufficient to cause death.

While there is evidence that some fungicides may act on the cell wall it would seem to be a safe assumption that most fungicides exert their influence internally. The vast number of enzymatic reactions involved in the vital processes of the cell undoubtedly account for the major area with which a toxicant can interfere in a lethal manner.

Captan, for example, interferes with certain respiratory enzymes and thus eliminates or reduces the uptake of oxygen.

Dithiocarbamates can tie up heavy metals which are required to activate many metabolic processes.

Formaldehyde acts primarily as a protein denaturant.

Mercury is a general enzyme poison and is very effective even in small doses.

Fungicides which exert their lethal action within a cell must first be able to penetrate the cell wall and membrane. These membranes act selectively in excluding certain chemicals. Copper sulfate, for example, is not effective against the group of fungi known as powdery mildews because their spore walls contain a high concentration of lipids and copper penetrates lipids poorly.

Mercury is toxic to most fungi, but in inorganic form its value is limited because of poor penetrability of cell walls of some fungi. In an organic formulation, the organic portion acts as a spearhead to penetrate these walls more readily and thus transport the mercury into the cell. Differences in cell wall permeability determine to a large extent the fungicide which is most effective against a particular fungus.

CHOICE OF FUNGICIDE

Before a fungicide can be used effectively the applicator should be familiar with what he is attempting to control. He must know what species of fungus or fungi are involved. Although many fungicides are lethal to a wide range of fungi, there are many instances where the choice of the right fungicide will determine success or failure. A few examples may serve to illustrate this point.

The powdery mildews (a group of fungi very common and damaging to a wide range of plants) are best controlled by sulfur or Karathane (dinitro phenyl crotonate). Many other commonly available fungicides are ineffective against powdery mildews, and very often are damaging to the plants which they are supposed to protect.

Hexachlorobenzene is effective in seed treatment to control the fungus causing bunt of wheat. It is, however, specific to this fungus and will not control the root-rotting group of fungi. Mercurial fungicides, on the other hand, control the root-rotting as well as the bunt fungi but they have the disadvantage of being highly toxic to humans and also damaging to seedlings if used in slight over-dosage. Hexachlorobenzene is relatively safe to humans and seedlings. Therefore, if the bunt fungus were the only organism we were concerned with then obviously the fungicide hexachlorobenzene would be a more logical choice.

Formaldehyde is quite effective in eradicating seed-borne fungi, but it does not provide protection to the seedling in the soil, and is lethal to damaged seed. Organic mercurials are equally or more effective in eradicating seed-borne fungi, are less damaging to seed if used in proper dosages, and offer good protection to the seedling against soil-borne pathogenic fungi. Organic mercurials are, therefore, a better choice than formaldehyde for the control of seed-borne and seedling diseases.

WHEN, WHERE AND HOW TO APPLY FUNGICIDES

The time to apply a fungicide is particularly important under two situations:

1) when it is used to protect the foliage or fruit from invasion by a fungus, and
2) when it is used on plant material that is to be consumed.

A suitable period of time must be allowed between application and consumption to allow washing off or degradation of the chemical to reduce its toxicity. It would be impossible to list here these periods for all fungicides, but applicators must be aware of the importance of this consideration.

The timing of application for the most effective prevention of disease depends on the knowledge of the life cycle of the particular fungus. Spores are the chief means of fungus distribution and all fungi do not produce spores under the same conditions. It is particularly important to know the conditions under which spores are produced and dispersed in spring, since control of early infections will prevent disease epidemics later in the season. Application of a protective fungicide during periods when spores are not produced would be impractical.

In areas of intensive fruit and vegetable production there are usually special committees, consisting of plant pathologists, whose responsibility is to provide information as to when, how and what fungicides to use. This information is supplied in the form of spray calendars.

When to apply a fungicide may also be influenced by such factors as rains and temperatures. Certain chemicals, e.g. Karathane or sulfur should not be applied in hot weather (above 85°F.) because at these temperatures they are highly damaging to the leaves.

Where to apply a fungicide may be of prime importance under certain situations. For example, a fungus causing a scab on apples overwinters in dead leaves on the ground. In spring this fungus produces and ejects an abundance of spores to initiate infections in young apple leaves. Application of a proper fungicide as a ground spray to prevent spore production will reduce the early infections and thus minimize the possibility of epidemics of scab later in the season.

The problem of how to apply fungicides involves methods and equipment such as dusters and sprayers. A thorough coverage of material is essential and to accomplish this, equipment and formulation should be chosen carefully. Each situation presents its own problems. Whether to use a fungicide in dry powder or in wet form, whether the chemical is corrosive to equipment, and whether the equipment has been contaminated with weed killers, are just some of the considerations an applicator must be aware of. The use of proper equipment in a proper manner cannot be over-emphasized because if poorly handled all else may be in vain.

PRECAUTIONS

Fungicides vary in toxicity from the relatively harmless ones such as the dithiocarbamates, to the highly poisonous compounds such as organomercury and corrosive sublimate. The less poisonous compounds should be used whenever they are effective and practical. At present the most effective and economical compounds are the organic mercurials which also are quite toxic.

All fungicides should be considered poisons and handled with caution, especially the mercurials. Poisoning can occur by the compound being inhaled as a gas or dust, absorbed through the skin or taken by mouth. The acute oral LD_{50} value in rats for organo-mercurials is approximately 30 mg/kg. The total dose necessary to produce chronic poisoning in mammals is 6 to 24 mg/kg expressed as mercury. Most problems result from chronic poisoning since mercury accumulates in the body, particularly in the liver, kidneys and brain. Most excretion occurs through the urine and urinalysis is an important part of diagnosis.

Protection for the Applicator

Treating should be done in well-ventilated quarters or outdoors. Keep up-wind from sprays and dusts. Follow the manufacturer's directions and precautions and handle all fungicides with care. With most compounds and especially with organic mercurials, the use of a suitable face mask or respirator, rubber or plastic gloves and separate work clothing is necessary. For operators subject to prolonged exposure, special protective devices are recommended. Special closed treating machinery is available and exhaust fans should be used in seed-treatment rooms. All clothing, including shoes, should be changed after work or immediately upon being soaked by liquid compounds.

Smoking, chewing gum or tobacco, drinking or eating should be prohibited during work. Scrupulous personal hygiene is required. Workers should receive pre-employment medical examinations to exclude those with neurasthenia, nervous disease, dermatitis, liver disorder, hypertension or defective kidney function. Persons with repeated exposure should receive periodic medical examinations and frequent, regular analysis of the urine for mercury.

Protection To Other Forms of Life

As with other pesticides, care should be taken with fungicides and with treated areas and products. Compounds should be stored out of reach of children, irresponsible persons and animals. The best storage is under lock and key. Keep poisons out of reach while they are in use. Store compounds in their original containers, properly labelled. Dispose of empty containers promptly and safely. Do not contaminate drinking water or fish habitat when cleaning equipment or filling spray tanks.

Precautions should be taken not to contaminate food or feed. There is no tolerance in food for mercurial compounds. It is a criminal offence to sell treated grain other than for seed. It should not be fed to animals. Even if diluted with non-treated grain sufficiently to cause no apparent harm to livestock, the level of fungicide could be harmful to human consumers of milk and meat. Treated grain should be clearly labelled in transit and in storage, and kept well separated from other grain and feed.

EFFECTS OF PESTICIDES ON MAN AND ANIMALS

TOXICITY OF PESTICIDES TO HUMANS

The toxicity of pesticides to man cannot be determined from factual experimental evidence. Clinical experiences with cases of accidental poisoning can give information on poisoning symptoms, side effects, or evidence of chronic toxicity, but these case histories cannot provide lethal dosage levels. This information must be interpreted from toxicity experiments with small mammals such as mice, rats, dogs and rabbits.

Toxicological research has shown that the susceptibility of mammals to pesticides varies with the species, age, sex and nutritional state of the animals being tested as well as by the route of administration and formulation of the poison. Therefore, data on comparative toxicity values, as determined from small mammals, can serve only as a guide to the probable toxicity level for humans. However, such data does categorize the compounds into order of toxicity and indicate how these materials should be handled.

The majority of fatal and nonfatal cases of accidental poisoning, especially among small children, have been caused by solid and liquid substances that are listed as relatively non-poisonous. Thus, the toxicity of a compound does not necessarily infer its potential health hazard, but rather the hazard involved is dependent on how a substance is used and abused.

INTERPRETATION OF TOXICITY DATA AND HEALTH HAZARDS

The Acute Toxicity of a pesticide to mammals is determined from applying integrated doses of the actual compound to a large group of test animals. From these experiments, various levels of mortality are obtained but in most instances only the LD_{50} values are quoted. This value is that single dose of actual compound that will kill 50% of the test animals. These acute toxicity levels are determined for several routes of absorption, such as by

oral feeding, by absorption through the skin, by injection into the body and by inhalation. Two statistics are used for comparative toxicity purposes. These are the Acute Oral Toxicity, which is expressed as the LD_{50} value when the compound was fed to test animals, and the Acute Dermal Toxicity as the LD_{50} value when the compound was applied directly to the skin. These dosage levels are usually expressed as milligrams of pesticide per kilogram of body weight of the test animal (mg/kg). The term 'part per million' may also be used (1 ppm - 1 pound per million pounds or 1 mg/kg).

Chronic Toxicity studies are more extensive in nature and may continue for days to throughout the lifetime of the test animals. In these studies, repeated sublethal doses of pesticides are applied by various routes of absorption to determine the accumulative effects of the poison, its mode of action, its effect on reproductive and other organs, and an insight into any side effects that may be potential hazards to humans. The compounds that may induce cancer or other serious side effects in humans are excluded from further testing and discarded.

With the tabulation of the toxicity data of various compounds, comparisons of toxicity levels can be made and interpreted for humans. Scientists in the United States have developed a general guide to the probable lethal dose for human adults that is based on the acute oral toxicity of pesticides to rats:

Acute Oral LD_{50} Rats - mg/kg		Probable Lethal Dose for Adult Humans
less than 5	....	a few drops
5 to 50	....	up to a teaspoon
50 to 500	....	two teaspoons
above 500	....	over one ounce

In addition, a broader guide for the consumer use and handling of pesticides comes from Great Britain and is as follows:

Highly Toxic - Trouble may be encountered through application with compounds of dangerously high toxicity and appreciable hazards. These require careful handling under almost all circumstances and include compounds of oral toxicity levels at 10 to 50 mg/kg.

Moderately Toxic - These are moderately toxic compounds that are safe if used with some care, and care is especially needed in hot climates, indoors, and when handling concentrates. They include compounds having oral toxicities of 50 to 500 mg/kg.

Slightly Toxic - These are compounds considered to be of low mammalian toxicity and correspondingly slight hazard in use. These include compounds having oral toxicities of 500 to $<$ 5,000 mg/kg.

The duration of personal exposure, carelessness of handling and application, and general misuse may cause poisoning with even the so-called safe compounds. Repeated small dosages and over-exposure may cause these poisons to accumulate to dangerous levels in the persons handling or exposed to the pesticide.

THE COMPARATIVE TOXICITIES OF INSECTICIDES

The toxicities of the common insecticides to small mammals are given in Tables 1 - 3. These insecticides will be discussed in related groups with respect to their mode of action, antidotes, toxic symptoms, and pertinent information regarding human poisoning.

The chlorinated hydrocarbon insecticides as a group are the most persistent pesticides in use (Table I). Their basic mode of action in mammals is unknown, but they are central nervous system stimulants that promote the action of acetylcholine centrally leading to convulsions. Carbon tetrachloride, a well-known kidney and liver poison, may be classed with this group but as a whole these insecticides are not chronic liver poisons. They are, however, readily stored in body fat and minute amounts in animal feed can be detected in the milk of dairy cattle. Repeated exposure to small doses may cause these compounds to accumulate in fat and organs of mammals including humans. There is no known specific antidote for these compounds.

Ingestion, inhalation, or skin absorption of a toxic dose induces nausea, vomiting, muscular weakness, confusion, hyper-sensitivity tremors, epileptic convulsions, and ventricular fibril-lation in mammals. With the more toxic compounds of this group, acute illness in humans may follow as early as twenty minutes after exposure. In cases of poisoning with the less toxic compounds, acute poisoning symptoms may not occur for 3 to 4 hours after exposure. Recovery in non-fatal cases is usually within 24 hours. Death from these compounds occurs from respiratory failure or ventricular fibrillation

TABLE I

Comparative Acute Oral and Dermal Toxicities of Chlorinated Hydrocarbon Insecticides to Small Mammals

Compound	Oral mg/kg	Dermal mg/kg
Endrin	3 - 6	60 - 120
Endosulfan	35	360
Lindane	200	500
Chlordane	283	1,600
Toxaphene	283	1,000
Methoxychlor	6,000	6,000

TABLE II

Comparative Acute Oral and Dermal Toxicities of Organophosphate Insecticides to Small Mammals

Compound	Oral mg/kg	Dermal mg/kg
Phorate	2-3	70-300
Mevinphos	3-5	90
Parathion	3-6	75-200
Azinophos-methyl	7-13	280
Parathion-methyl	12-16	67
Carbophenothion	7-30	800
Ethion	13	1600
Phosphamidon	15	125
Bidrin	22	225
Dichlorvos	25-30	75-900
Coumophos	90-150	860
Ciodrin	125	385
Fenthion	200	1300
Dimethoate	200-300	750-1150
Diazinon	300-600	1200
Naled	430	1100
Trichlorfon	650	2800
Ruelene	950	--
Ronnel	1250-2630	1000
Malathion	1400-1900	4000

TABLE III

Comparative Acute Oral and Dermal Toxicities of Miscellaneous Insecticides To Small Mammals

Compound	Oral mg/kg	Dermal mg/kg
Carbamates		
Dimetilan	25-50	600-700
Carbaryl	400	500
Botanicals		
Nicotine	70	140
Rotenone	200-1500	1000
Pyrethrum	570	1800
Inorganic compounds		
Paris green	22	-
Calcium arsenate	35-100	-
Lead arsenate	100	2400
Metaldehyde	600-1000	-
Synergists		
Piperonyl butoxide	11,500	-

The Carbamates are reversible inhibitors of cholinesterase and poisoning symptoms are similar to that of the organophosphate insecticides. These are a relatively new group of compounds with most of them still in various stages of development. Some of the carbamates are extremely toxic but most of them are of intermediate hazard. Atropine sulphate is antidotal but 2-PAM or other oximes are not recommended.

The Botanicals or plant derivatives are a relatively safe group. Nicotine, as nicotine sulphate, is the most toxic. Its primary action is as a stimulant to the nervous system, then a depressant with ultimate paralysis and functional failure of the vital organs. It is rapidly absorbed by the skin and symptoms have been reported in spray operators when using only a 0.1% nicotine solution. The other compounds in this group present very little health hazard to man.

The Inorganic Compounds listed in Table III are in limited use today. Paris Green, a combination of copper and arsenic trioxide, is highly toxic to man when taken by mouth. Arsenic trioxide has been known to cause skin cancer. The arsenate forms are less toxic.

Piperonyl Butoxide, a synergist, has a very low hazard and is usually employed as a knock-down agent in aerosols, sprays, and dust formulations where other ingredients are the main insecticidal agents.

Fumigants - are volatile materials that readily give off insecticidal vapours. Most of these compounds are extremely hazardous to man and should be used only by trained personnel and with extreme care. The threshold limit for each compound in air is included, which is that concentration in air that can be tolerated by man for short exposure periods. Concentrations beyond these values can cause poisoning. Fumigation of stored grain on farms by untrained operators has led to accidents where improper protective equipment had been used and improper precautions followed.

THE TOXICITY OF SOLVENTS AND ADJUVANTS

In pesticide formulations, the OTHER ingredients are often listed as being inert. This is probably so with respect to dusts, and likewise with emulsifiers, surfactants, and wetting agents, because the latter are in very low concentration. However, solvents and other carriers may contribute to the danger of the pesticidal formulation. This is especially so with emulsifiable concentrates and oil solutions. The solvent may act through its own inherent toxic action to humans or because of its solubilizing action on the pesticide, making the latter more volatile, or readily absorbed when spilled on the skin.

Kerosene is an example of petroleum distillate that is often used as a pesticidal solvent. This compound is absorbed through the respiratory and digestive tract. It is a common cause of illness and poisoning, especially when young children have swallowed a household formulation of a pesticide. Survival in humans has followed ingestion of one litre but death has been caused by ingestion of only 30 ml. Chronic intoxication has not been reported.

Xylene is an example of the aromatic hydrocarbon solvents and is commonly used in insecticide formulations. Humans exposed in a poorly ventilated area to Xylene or related compounds, may suffer from headache, disturbed vision, dizziness and nausea. Severe exposure may lead to collapse and coma.

The Freons are a series of fluorinated-chlorinated hydrocarbons that are used as refrigerant gases. Because of their properties some of them are used as propellent gases in aerosol formulations. By themselves the Freons are considered non-toxic although inhalations of high concentrations may cause pulmonary irritation and confusion. However, these propellent gases can be dangerous when the aerosol is directed into an open flame, since some of the Freon is converted into a deadly gas phosgene.

BASIC FIRST AID IN THE EVENT OF ACCIDENTAL POISONING

In cases of accidental poisoning whether known or suspect Call a Physician Immediately. Take the patient to the nearest hospital and have them contact the Poison Control Centre for the specific antidote and treatment. Make sure that the pesticide container label is brought to the hospital with the patient. This lable will list the toxicant involved and will contain important information regarding antidote and treatment.

Where a poison has been spilled on the skin, remove all contaminated clothing and wash immediately with soap and water. Soap will remove the poison from the contaminated area and water will help to dilute it before absorption. Flush out eyes immediately with water. It is important in this instance to watch the victim for signs of intoxication and, if suspect, take him to hospital immediately.

When a poison has been known to be swallowed, empty the stomach by induced vomiting, such as giving orally one teaspoonful of salt in a glass of warm water until the vomitus is clear. Keep the patient quiet and warm and do not give sedatives. Notify your doctor and get the victim to medical attention as soon as possible.

TOXICITY OF PESTICIDES TO LIVESTOCK

The general principles of toxicity of pesticides to livestock are the same as those discussed for humans. Basically, anything taken in excess is poisonous, and this includes even such common and essential items of daily food as water and table salt. Sometimes, however, toxicity may be caused by a therapeutic dose. This is because of several factors such as biological variations in individuals, stress, latent infections, toxins released by the parasites killed in the body of the host by the action of pesticides, chemical properties of pesticides as influenced by storage and handling, etc.

Livestock are exposed to pesticides either intentionally or accidentally. In either case, toxicosis is diagnosed by clinical examination and the history of exposure to pesticides. In living animals laboratory tests for diagnosing pesticide toxicity are of little value because remedial measures should not await the outcome of laboratory procedures.

This discussion will be mainly concerned with insecticides since they are involved in poisoiing livestock more than any other group of pesticides. A few herbicides also will be discussed.

The symptoms of acute poisoning are salivation, diarrhea tinged with blood , depression, muscular weakness, increased respiration and elevated temperature. Frequent micturition and bleeding from the nose and the lungs are also seen. The symptoms

or chronic poisoning develop slowly. There is depression, loss of appetite and weight, general weakness, anemia and paralysis of the hind limbs. Some animals go blind.

Chronic poisoning results from accumulation of mercury in the tissues and organs of animals. The symptoms of chronic poisoning follow the same pattern as those of acute poisoning, but their onset is slower.

Chlorinated hydrocarbons - The compounds commonly involved are BHC, Methoxychlor, Chlordane, Toxaphene, etc.

The commonly seen symptoms suggest a stimulant effect on the central nervous system but symptoms of depressant effect may be seen occasionally. The animals poisoned as a result of dermal application may have the smell of insecticide on their bodies. They appear alert and nervous. Their responses to sudden movements and noises are exaggerated. Excessive salivation, muscular tremors and ataxia are seen. In final stages the animal goes down in convulsions with violent paddling and kicking with all four limbs. The temperature may be below normal in the beginning of toxicosis, but is elevated later as the animal develops tremors and convulsions.

Organophosphates - A number of these compounds are on the market. Some of them are used on livestock, others on crops and farm buildings. Ciodrin, Coumaphos (Co-Ral), Diazinon, Neguvon, Ronnel (Korlan and Steer-Kleer), Ruelene and Vapona are some of the organophosphates used on livestock.

The symptoms of poisoning from all of these compounds are identical to a large extent as all of them affect the nervous system by inhibiting an essential group of enzymes called cholinesterases. The animals appear to be dull and depressed. There is a discharge from the nose and eyes, profuse salivation, and diarrhea. The animals have constricted pupils, muscular tremors, general weakness, wobbly gait and incoordination. Finally, paralysis and coma develop.

In certain cases these symptoms are complicated by lesions caused by irritant substances released in the esophagus and spinal canal by cattle grub larvae killed by the insecticide. The esophageal lesions - ulceration, inflammation and edematous infiltration - cause occlusion of the esophageal lumen resulting in excessive salivation and bloat. The former because the animal is unable to swallow the increased flow of saliva, and the latter because the gases cannot escape from the rumen. The spinal lesions cause ataxia and paralysis depending upon the severity of inflammation in the spinal canal and injury to the spinal cord.

Carbamates - The commonly used carbamates are Carbaryl (Sevin) and Snip (Dimetilan). These compounds also inhibit cholinesterase and the symptoms of poisoning by these compounds are similar to those caused by organophosphates.

Herbicides:

Dinitrophenols, other dinitro compounds and pentachlorophenol are highly toxic chemicals. The clinical symptoms of poisoning by these compounds are nervousness, increased respiration rate, weakness, muscular tremors, convulsions and paralysis. The animals die in a coma. Additionally, dinitro compounds cause a rise in temperature and yellowing of the skin around the mouth and of the hair around the hoofs.

Sodium chlorate - Dyspnea, respiratory distress, breathing through the mouth, nervousness, weakness, ataxia and diarrhea are the more commonly seen signs of poisoning.

Arsenicals - Arsenic poisoning may be acute or chronic. Profuse diarrhea, which may contain blood, mucous and shreds of mucous membrane, dehydration and increased thirst, abdominal pain, twitching of muscles, weakness and ataxia are common symptoms of acute poisoning. Scalding, cracking and peeling of the skin and loss of hair may be seen if arsenic has been applied to the skin of animals.

The onset of symptoms of chronic arsenic is slow and insidious with gradual loss of appetite and weight. The symptoms, in general, resemble those of acute poisoning.

Plant hormones - Hormones 2,4-D, MCPA, etc., are non-toxic to cattle in small doses but cause impaction of rumen, loss of appetite and weight, neuritis and muscular weakness, particularly of the hind limbs, if absorbed in the animal system in large quantities.

THE EFFECTS OF PESTICIDES ON WILDLIFE

Since there is a tendency in North America to consider wildlife as solely consisting of game birds and mammals, a definition should first be made. Wildlife, in the context to be used in this lesson, includes all animals (birds, mammals, fish, insects, etc.) not domesticated by man.

There are two main ways in which pesticides affect wildlife:

1) direct mortality, and

2) changes in behaviour or physiology so that reproduction is adversely affected.

These effects arise either from direct contact with the chemical or ingestion of treated food, or indirectly from loss of habitat, shelter or food due to pesticide use. Examples of these effects are:

1) birds seen dying after they have eaten worms from treated lawns;

2) the destruction of habitats of many birds and mammals through the use of weed killer over extensive areas;

3) the decline of fish population due to the killing off of their normal food (insects) with insecticides.

The pesticides which are implicated in wildlife losses are normally those which are used to control agricultural and forest pests and those which are used against insects which annoy or bite man. These are pesticides which are generally applied over large areas such as grain fields attacked by grasshoppers, forest stands attacked by defoliating insects, or large urban areas and park areas treated for the control of mosquitoes. Under these circumstances it is very difficult to confine the pesticide to the target pest. The chemicals enter water in ponds and sloughs, or streams directly, or they leach off treated fields. Aquatic animals thus come into contact with the pesticide. When a forest is sprayed with pesticides the chemicals also deposit on birds and mammals and fish where they often exert a toxic effect, or they may contaminate the food of many forms of wildlife.

One of the insidious aspects of pesticides, notably insecticides, is the way they become concentrated at the higher end of a food chain. For example, a very low concentration of insecticide initially applied to water (for control of mosquitoes or midges) is concentrated by minute organisms called plankton. These are consumed by insects which further concentrate the chemical. This food chain continues through other insects, then fish, then birds such as ducks and ospreys, and in the latter group the insecticide may have been concentrated four to five hundred times the initial concentration in the water. It is because of this concentration in food chains that predators, whether they be fish, birds or mammals, are in serious jeopardy in some sections of the country. This is due partly because they consume food containing large residues of pesticides and partly because they reproduce much more slowly than herbivores.

It is obvious that we must continue to protect our crops, stored products and domestic animals from various pests, but there are certain precautions which must be taken during pest control operations to reduce the deleterious effects of pesticides on wildlife.

The label on the pesticide container should, of course, be read and the directions as well as the recommendations of the agricultural or other official advisors, be scrupulously followed. Overdosing is a common practice and one which seems to the average person to be a sure way to obtain even greater control. The side effects of such practice could be serious as mentioned, and the operator should always keep this in mind when calibrating his apparatus for a particular application. It is imperative that the proper insecticide and formulation be used against a specific pest and the proper disposal of containers and excess material should be carried out. Never dump old chemicals or the spray left in the tank after an operation into streams or ponds. Disposal procedures are outlined elsewhere in this syllabus. Whenever possible the pesticide should be directed against the target organisms only. Turn off sprayers near water sources or habitants of wild animals such as hedgerows and roadsides and woodland. Do not apply pesticides on windy days to avoid drift of the chemicals to other areas. Finally, keep in close touch with provincial, federal, and university officials who are only too willing to give advice on any aspect of pest control.

METHODS OF APPLICATION OF PESTICIDES

Pesticides may be dispersed as sprays consisting of solutions, emulsions or suspensions, in which either water or oil may or may not be the carrier. Pesticides may also be dispersed as a dust in which a fine powder is the carrier for the pesticide. They may also be applied as gases and aerosols.

Pesticides are widely used to control weeds, insect or disease organisms throughout a wide variety of situations.

Before pesticides are applied there are three basic essentials to obtain effective control:

1) have carefully operated and properly adjusted and maintained equipment;

2) the proper timing of the application; and

3) using the correct material at the proper dosage to do the job that is needed.

SPRAYS

The term "spray" is used to cover all liquid droplet applications of pesticides. The kind of spray to be used will depend on a number of factors including toxicity and volatility of pesticide; area to be covered (indoors or outdoors); method of application (aircraft, boom-sprayer, etc.); coverage required (complete or otherwise); nature of pest (flying, on horizontal surfaces, under foliage, on ground, etc.). It is not possible to anticipate all the factors mentioned above, but the following general points may be pertinent:

(a) It is economically important to obtain maximum control of the pest using the minimum of pesticide, and utilizing a minimum time and cost of application.

(b) Complete sprays requiring total coverage of the infected surfaces are often needed to control fungus and bacterial infections, as well as stationary insects (e.g. aphids)

which obtain nutrients from within plants and often have a protective waxy coating. A high power spray is required for this purpose and the droplets must have maximum spreading power.

(c) The size of droplet obtained is very much dependent on the atomization equipment used and also on the formulation of the pesticide. In acqueous sprays the presence of wetting agents will decrease the size of droplet and increase the spreading power. If an oil-based (e.g. kerosene) pesticide is used, the spreading power of the droplets is about five times that obtained with water-based formulations (without wetting agents present). However, water-based sprays are the most popular because water is the cheapest and most readily available solvent for diluting concentrates and wettable powders.

(d) Spray produced by air atomizers tends to remain as separate drops, whilst spray produced by pressure atomisers will have drops which tend to coalesce (i.e. the larger drops tend to pick up the smaller ones) unless carried away and diluted by wind.

(e) Both water and solvent-based droplets are subject to evaporation (as mentioned in (c) above), and the very small drops may easily lose their solvent unless a low volatility carrier is incorporated (e.g. mineral oil).

(f) The optimum droplet size for complete sprays, application to foliage, etc., is between 30 and 80 microns. For ground application, (e.g. herbicides) a droplet size in the region of 70-120 microns is best. For complete sprays the smaller droplet size is required so that foliage, etc., is adequately covered before the drops fall to the ground.

(g) Application of sprays from aircraft requires particular attention to wind drift. For example, if an airplane is flying at a height of 20 feet in a wind of 6 mph, the particles will be subject to drift from 76 to 192 feet if they are between 100 and 200 microns in size. Therefore, for accurate application of pesticides from the air, the absence of wind and correct choice of drop size are prime requisites.

(h) 'Knock-down' sprays for the control of flying insects, (and certain contact insecticides which are also effective in the vapour phase, require very small droplets, around 10 microns or smaller, so that they will remain suspended in the air for some time. This will increase the rate of contact and the contact time between the insect and the droplets.

DUSTS

Dust containing a pesticide is particularly useful when water is not conveniently available, or in applications by aircraft when the payload of the machine is limited. In general, the rules mentioned above in relation to particle size and drift of sprays are equally applicable to dusts. Naturally, the spreading power of dust is less than for liquid droplets, because the dust particles are incapable of increasing their area on contact with a surface. This limitation can be overcome by using the "wettable powders" in spray where water is available.

Dusts have the disadvantage that the particles may not stick to vertical stems and on the undersides of foliage, and also a strong breeze may cause them to be blown away from the treated surface. Many dusts contain sticking agents which increase adherence to surfaces, and if the correct particle size is chosen, reasonable distribution on foliage may be attained.

For the control of insect pests, carefully formulated dusts may be more efficient than sprays when applied to foliage near the ground. Materials which are short-lived as residues, or which kill in the vapour phase (e.g. nicotine, sulphur, TEPP) are effectively used in the form of impregnated dust, since slow release of the pesticide is attained together with adequate distribution.

SPRAYERS

The numerous types of sprayers and dusters all have peculiar advantages and disadvantages which suits them to the amount and kind of work to be done. Some of the basic characteristics of these applicators are as follows:

Air Blast Sprayers - liquids, water or petroleum solvents are atomized and dispersed by a stream of air. The direction and coverage obtained is determined by the blast of air carrying the droplets.

A popular household unit of this kind is the flit gun. The spray obtained is intermittent but these units are cheap and suitable for household or backyard use. A similar sprayer using a continuous blast of air from a motorized air-compressor has some use commercially where the power supply is no problem. Compressed air point-sprayers operate on this principle.

Mist or concentrate sprayers also utilize the air blast for large scale orchard, ornamental and roadside spraying. Nozzles spray liquids into a large blast of air which further break down droplet size and carries them to location. Large fans run by motors supply the air and application occurs only when nozzles are turned on. These machines are expensive and are most suited for use with high value horticultural crops.

Compressed Air - Some hand-operated units use air obtained from a hand-operated air-pump for pressure on the spray solution. Increasing the pressure increases the range of this equipment and nozzles are adjustable for further versatility. The spray obtained is continuous but use of this type of sprayer is somewhat limited by the capacity of the pressure tank which also acts as the reservoir for the spray solution.

Aerosol bombs are similar to these units but the compressed air is supplied from a liquid with a low boiling point, called a propellant. The unit itself is sealed and charged when assembled at the factory. The discharge valve and nozzle are usually incorporated and the energy to discharge the spray is provided by the propellant. Because of their convenience and light weight, aerosol bombs are usually used around homes. Some bombs apply other types of pesticides but the expense of the non-refillable pressure can make this type of unit too costly for other than specialty usage.

Hydraulic Sprayers - Spray solutions are forced directly through the nozzles by the action of either hand-driven or motorized pumps. The hydraulic sprayers with gear pumps should not be used for the dispersal of wettable powder suspensions because of the excessive wear on that type of pump by the abrasive action of the powder. These sprayers are useful around buildings for control of houseflies, mosquitoes and other insects. With these sprayers liquid is forced through a nozzle which breaks up the fluid into droplets. The droplet-size and range of the spray obtained depends directly on the pressure at which the liquid is forced through the nozzle and on nozzle design. Some nozzles are adjustable and will give a fine mist to a jet of water.

Dust Sprayers - A number of insects and plant diseases may be controlled more effectively and economically with dusts than with the liquid sprays. Many acres of horticultural and orchard crops are dusted yearly with various kinds of insecticides and fungicides.

Dusters are more likely to be found in garden use of vegetable culture.

Dusts may be applied by hand dusters, power take-off dusters or engine dusters and to a limited extent aircraft-equipped dusting units. Hand dusters are particularly useful in introducing insecticides into crevices. A multiple dusting unit was developed for control of body lice on clothed personnel.

The power-operated duster uses a blower to produce an air blast into which the dust is fed. These are useful in large scale dusting of crops or shelterbelts as assistance to sprayers when immediate action in the control of a pest is necessary.

SOME APPLICATION POINTS TO CONSIDER BEFORE BUYING A SPRAYER

Three popular types of sprayers are being used in Canada at the present time. These are trailer-mounted, tractor-mounted and swather-mounted machines. The trailer-mounted machine may have the pump driven by the power take-off on the tractor that pulls it or self-powered by an auxiliary motor mounted on the trailer. The swather-mounted type is usually run by the swather motor or the pump may be driven by a separate motor.

The trailer unit is a complete unit and is probably the most convenient type of spraying equipment because it can be hooked up to a tractor quickly and unhooked quickly so that the tractor may be used for other work at any time.

The tractor-mounted sprayer almost always has the pump powered from the power take-off. This sprayer may be inconvenient in that the sprayer may have to be mounted and dismounted several times during the spraying season so that the tractor may be used for other jobs. It is the cheapest type of the three outlined.

The swather-mounted sprayer is usually run by the swather motor or the pump may also be driven by a separate motor. On this machine the sprayer assembly will only have to be mounted once during the spray season and left until the swather is needed for fall harvesting when it will have to be dismounted.

The following features should be considered before a sprayer is purchased:

(a) The sprayer tank - tanks are commonly built of steel, galvanized steel, aluminum or aluminum alloy. Stainless steel tanks are also available. Steel tanks corrode readily and are not recommended. Galvanized steel tanks will give good service if properly cared for but they may eventually corrode. Aluminum or aluminum alloy tanks are more satisfactory in spite of the higher initial cost. Stainless steel tanks are very expensive and are only recommended if highly corrosive material is to be used.

(b) Size of tank - The tank should not be larger than 80 gallons for the tractor mounted types and not larger than 200 gallons for trailer sprayers. The tire size on the trailer should be large enough so that there is a minimum amount of compaction and crop damage. The tank should have a reasonably large opening, particularly for cleaning purposes. The tank should also have a drain plug in the bottom to facilitate cleaning and draining for changing chemicals and servicing before storage.

(c) Power - units should be powered by motors having sufficient power to insure long life and have adequate horse power to operate a pump suitable for the length of the boom and number of nozzles to be used. The pressure loss at the boom end is not too great, <u>only 3 psi for each 10 feet of a 1 inch tube</u>.

(d) Pumps - High pressure expensive pumps are not necessary when applying ordinary liquid pesticides, but special pumps are required for handling abrasive materials. A pump must have sufficient capacity to maintain the required pressure plus a sufficient flow through the return hose to properly agitate the solution in the tank. It is an advantage if the pump is large enough to fill the tank rapidly.

(e) Controls - The necessary controls consist of a pressure gauge which should be of a reliable make and have sufficient capacity to accurately determine the pressures. There should be control valves for the boom and return hoses. There should be a valve for filling the tank through a pump. All the controls should be grouped together and situated in a convenient position.

(f) Filters and screens - Many types of filters and screens are available - screen felt, paper, etc. Felt on screen types are preferred as they can be cleaned frequently. All the filters should be fitted so they are readily accessible for

replacement or cleaning. An efficient filter or screen should be provided between the pump and the boom and each nozzle outlet should be protected by a proper screen. The size of mesh in a screen should be smaller than the orifice in the nozzle being used.

(g) Sprayer booms - Most of the booms are made of aluminum or copper and both these materials resist corrosion. The aluminum boom is more rigid than the copper, therefore, a longer boom of aluminum may be used without bracing. Booms up to 33 feet in length may perform satisfactorily on level, smooth ground without caster wheels. The booms should be mounted in such a way as to be readily adjusted for height and the ends should be capped to facilitate cleaning.

(h) Back-flow prevention device - to prevent water contamination when water is drawn from an open stream. See Regulations under the Pesticides Act.

OPERATION OF A SPRAYER

Correct application ensures that the full effectiveness of the pesticide chemical will be realized. The manner in which the pesticide is used will depend on the pest being controlled, the properties of the pesticide and the location of the infestation. The best method to use will be the one that puts the pesticide in contact with the greatest number of pests and gives the smallest side effects on the surrounding environment.

For maximum benefit the chemicals must be applied safely and accurately. The following practices will help to achieve the results required for a successful application:

1. Use clean water, as dirty water will clog the filters and screens or the orifice of the nozzles. The dirt in the water will also wear the pump and valves.

2. Clean and lubricate the sprayer daily to avoid clogging and check on the working parts so they may be replaced or repaired before the spray operation in the field.

3. Calibrate the sprayer - after the sprayer has been properly checked and adjusted it may be calibrated by the following procedures:

(a) How to determine the gallon capacity of sprayer tanks:

Type of Tank	Calculation of Capacity (Imperial Gallon)
Cylindrical Tank (or Circular Cross Section)	Multiply length in inches by square of diameter in inches by 0.00283 = gals.
Elliptical Cross Section	Multiply length in inches by short diameter in inches by long diameter in inches by 0.00283 = gals.
Rectangular Tank (Square or Oblong Cross-section)	Multiply length by width by depth by 0.00361 = gals.

If the tank doesn't have a gauge and the shape of the tank does not lend itself to one of the above shapes, then a measuring stick may be constructed and kept with the sprayer. Every time ten gallons of water is added (five gallons if it is a small tank) make a deep notch to mark the level of the stick. The measuring stick will eliminate guess-work when using less than a tankful of spray to finish a job.

(b) How to calibrate boom sprayers:

1. Measure width of boom in feet or with row-crop sprayers, the width in feet covered by rows sprayed (4 rows covered 22 inches apart = $\frac{88}{12}$ feet).

2. Divide the width of the boom into 43,560 (number of square feet in an acre) to get the number of feet of travel necessary to cover one acre.

3. Measure off a known distance: the number of feet of travel to spray one acre or a fraction thereof.

4. Fill your supply tank full of water.

5. Spray the measured distance (as found in 3) as you would spray the field. Note - speed of tractor and pressure of sprayer.

6. Carefully measure the number of gallons of water required to refill the tank. This is the volume sprayed.

7. Convert the volume sprayed to volume per acre delivered by the sprayer at a given speed and pressure.

8. The volume per acre delivered (7) divided into the volume of the tank will give the number of acres a tankful of spray will cover. This is the area-capacity of the tank at that pressure and speed and for the type of boom used.

9. Add the amount of pesticide recommended per acre, multiplied by acre-capacity of the tank, to the empty tank and refill with water.

   Example: 20 gallons per acre were applied in the trial run. The tank holds 250 gallons. The specified rate of application of pesticide is 5 pounds per acre. Hence $\frac{250}{20} \times 5 = 62.5$.

   Therefore, it is necessary to add 62.5 pounds of pesticide per tankful of water.

The following table shows the acreage covered by different spray widths over one-half mile distance.

Sprayer Width	Acreage Covered	Sprayer Width	Acreage Covered
30	1.82	46	2.79
31	1.88	47	2.85
32	1.94	48	2.91
33	2.00	49	2.97
34	2.06	50	3.03
35	2.12	51	3.09
36	2.18	52	3.15
37	2.24	53	3.21
38	2.30	54	3.27
39	2.36	55	3.33
40	2.42	56	3.39
41	2.48	57	3.45
42	2.54	58	3.51
43	2.60	59	3.57
44	2.66	60	3.64
45	2.72		

Example - a 35-foot sprayer travelling one-half mile will cover 2.12 acres.

Field sprayers are rarely fitted with erosion-resistant tungsten carbide nozzles. Erosion of nozzle apertures is an ever present threat to accurate work. Under normal use the nozzle output may increase by a third or more after a month of operation. If silted water or an abrasive type wettable powder is used, the increase in output will be still greater. Most of the nozzles on power driven constant speed sprayers are either fan nozzles or hollow cone nozzles. All worn nozzles should be replaced. The worn nozzle may be detected by calibration against the specifications from the manufacturer.

If buying a low volume sprayer or replacing nozzle parts, try to get tungsten carbide aperture plates and swirl plates. They cost more than other types but are far more resistant to wear and ensure an accurate spray dosage over a longer period of time. Tungsten carbide is harder than glass and very brittle. Care must be exercised when installing.

SPRAY ATOMIZATION OF LIQUID PRESSURE, CONE TYPE NOZZLES

Pressure (p.s.i.)	Nozzle orifice diameter (inches/100)	Output per hour (gal.)	Droplet diameter (microns)	
			Average	Maximum
	2	1.5	65	170
	4	5.8	85	220
50	6	13	130	270
	8	22	180	330
	10	29	220	400
	2	2.1	60	160
	4	8.1	80	190
100	6	18	120	240
	8	31	200	290
	10	42	200	330

The above table is given so that some practical idea may be obtained of the inter-relationship between nozzle diameter, pressure, consumption and droplet size for a particular kind of sprayer. Most good quality commercially available sprayers should have all these details provided in the instruction manual.

RATE OF APPLICATION FOR SOME COMMON NOZZLES USED IN SPRAYING

Nozzle	Pressure In Pounds Per Square Inch	Imperial Ounces Per Minute	Imperial Gallons per acre at 3 MPH.	4 MPH.	5 MPH.
Monarch No. 22	30	7.7	4.9	3.6	2.9
	40	8.8	5.6	4.2	3.3
	50	9.9	6.2	4.7	3.7
Tee Jet 650067	30	8.0	4.7	3.6	2.8
	40	8.9	5.5	4.1	3.3
	50	9.3	6.2	4.6	3.7
Monarch No. 32	30	16.0	10.0	7.5	6.0
	40	17.3	10.8	8.2	6.5
	50	18.7	11.7	8.8	7.0
Tee Jet 650015	30	17.3	10.7	8.1	6.4
	40	20.0	12.4	9.2	7.4
	50	22.6	13.9	10.3	8.3
Monarch No. 39	30	26.7	16.6	12.5	10.0
	40	30.1	18.8	14.1	11.3
	50	37.6	23.6	17.5	14.1
Tee Jet 6502	30	22.6	14.3	10.7	8.6
	40	26.6	16.7	12.3	9.8
	50	30.6	18.3	13.7	11.0

This data is based on 20 inch spacings of nozzles - for 18 inch spacings add 1/10.

Note: The Tee Jet nozzle numbers refer to the performance of that nozzle, e.g. T650067 - the first two numbers refer to the angle the spray leaves the orifice, e.g. 65 = an angle of 65°. The next letter "0" acts as a space or decimal point and the last 3 letters "067" gives the number of gallons the nozzle will deliver in one minute at 40 psi (.067 gal./min.)

METHODS OF CALCULATING AMOUNT OF PESTICIDE TO USE

Chemical control recommendations are usually given in pounds or ounces of actual toxicant per acre. The lable on the container should have the amount of active toxicant stated. It is often desirable to be able to obtain the same strength spray using a different formulation or a different amount of water. The following formula may be used in making these calculations:

(a) How to figure the gallons of emulsifiable concentrate needed to mix a spray containing a given percentage of active ingredient:

Formula: $$\frac{\text{gal. spray needed} \times \%\ \text{toxicant req.} \times 10}{\text{pounds of toxicant per gal. of E.C.} \times 100.}$$

Example: How much 50% malathion (5 lb. per gal.) is needed to make 10 gal. of 0.5% malathion spray?

$$\frac{10 \times 0.5 \times 10}{5 \times 100} = 0.1 \text{ gal. and fill to 10 gal.}$$

(b) How to figure the number of pounds of wettable powder needed to mix a spray containing a given percentage of toxicant:

Formula: $$\frac{\text{gal. spray needed} \times \%\ \text{toxicant req.} \times 10}{\%\ \text{toxicant used.}}$$

Example: How many pounds of 25% wettable powder DDT are needed to make 100 gallons of spray containing 0.5% toxicant?

$$\frac{100 \times 0.5 \times 10}{25} = 20 \text{ lb.}$$

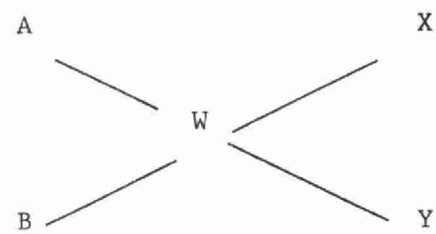
(c) How to figure percent active toxicant in a spray mixture:

Formula: $$\frac{\text{pounds of insecticide used} \times \%\ \text{active ingredient in insecticide}}{\text{gal. of spray mixture} \times 10}$$

Example: 10 pounds of 50% DDT wettable powder were mixed in 50 gal. of water. What percent active DDT was in the spray?

$$\frac{10 \times 50}{50 \times 10} = 1\% \text{ active DDT.}$$

(d) To dilute a concentrated solution, suspension or emulsion, make sure it is well mixed. Then calculate as follows:



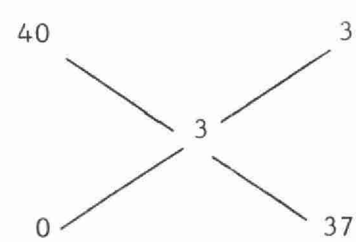
A - is the percent toxicant in the concentrate.

W - is the wanted percent.

B - is the percent in the diluent (normally zero because it is generally water).

A minus W gives Y: W minus B gives X, therefore - X parts of A mixed with Y parts of B will give the desired concentration.

Example: To dilute a 40% solution concentrate to a 3% oil or water solution:



Therefore, mixing three parts of the concentrate with thirty-seven parts of the oil diluent by volume will ordinarily be sufficiently accurate.

HOW TO CLEAN OR DECONTAMINATE A SPRAYER

If a sprayer must be used for an insecticide or fungicide after it has been used for herbicides, then it should be cleaned carefully and thoroughly. The recommended procedures are given here, but caution should be used as they do not guarantee complete protection for some of the more highly susceptible plants.

1. Fill the tank and system with clean water and flush it out, repeating three times.

2. Fill the tank with a strong solution of washing soda, baking soda or household ammonia (1 cup ammonia to 3 gallons water). Allow this to stand in the sprayer at least 24 hours and possibly 2 days after having recirculated the solution through the system for a few minutes.

3. Pump out the solution.

4. Wash out the sprayer with soapy water and rinse two or three times with clean water.

5. Do not wash in any streams of water. See Regulations under the Pesticides Act.

STORAGE OF THE SPRAYER

Prior to storing the sprayer for the winter the following conditioning is recommended:

1. Run water into the tank to the level of agitator shaft.

2. Add a gallon of fresh premium motor oil.

3. Operate the pump at full speed to mix and circulate the oil and water. This procedure coats the inner surface of the sprayer with oil.

4. Drain the tank.

5. Remove all drain plugs and remove the strainers so that there will be no frost damage.

6. Leave the filling cover off so that the water will evaporate from the tank.

7. Store the sprayer under cover. If no storage shed is available use a tarpaulin.

EFFECT OF ENVIRONMENT ON APPLICATION

Weather

The larger the droplets the faster they will fall to the surface of the area being sprayed. It is generally agreed that a droplet of at least 80 microns in size is desirable to minimize the danger of drift. Tests and data have also shown that the interception of the plants by the spray or coverage was better with droplets above 80 microns in size. The conclusion was that the larger particles because of their weight and mass were carried directly along the flight path while the smaller particles were more apt to be deflected by an eddy of air around the stem or leaf.

An applicator should never spray in an excessive wind. The term 'excessive' is used because it is seldom one may find a day when there is no wind. Actually, in some instances, it is most desirable that there should be a slight breeze to carry the vapours and drift away from the operation or from a susceptible crop. It has also been shown that the 80 micron droplet size will have maximum drift of only 80 feet at wind speeds of 15 miles per hour. Some breeze is also desirable to put the pesticide into the crop. It has been observed that on a virtually windless day and the temperature fairly high that the pesticide tended to rise in a cloud behind the sprayer rather than be laid down on the foliage. This particular instance was the result of rising convection currents. Therefore, it has been found that spraying conditions are usually best in early morning when temperatures are low, humidity is high and turbulence is low. Temperatures not only affect the evaporation and volatility of the chemical but also affect the turbulence of the air. Temperature, therefore, has a relationship to drift by affecting convection currents.

Some pesticides are not effective below a certain temperature, therefore, it is extremely important that the label is read and understood so that the pesticide will be put on at the right temperature to realize the full effectiveness of it. Most pesticides should not be put on if it is raining or going to rain. The pesticide must have a chance to do the job it is intended to do.

Terrain

The effects of a vertical whip are:

1. On uneven ground the ends of a long unsupported boom whips up and down in a vertical boom whip.

2. The ground area covered by the end of the boom that is higher than recommended height, will receive less pesticide than suggested because the spray pattern is too wide.

3. Ground areas closer to the centre of the boom or the raised portion received greater coverage because of the overlap in the spray patterns.

4. On the other end of the boom where the boom is very close to the ground the coverage by the spray is highly concentrated and the spray patterns do not meet. With this pattern there will be areas not covered by the spray.

The effects of a horizontal whip are:

1. Rough ground, poorly braced booms, or a loose hitch between the tractor and sprayer, may give a horizontal boom whip.

2. The horizontal whip occurs when the wheel meets an obstruction such as a lump, stone or depression. The wheel is momentarily stopped. The boom on the same side of the sprayer stops and a heavy application of spray occurs while the boom is stopped. When the wheel clears the obstruction, a light application occurs because the boom wheel or caster is trying to catch up to the sprayer and then this area gets very little pesticide. As a result of horizontal boom whip, the area gets a pattern of light and heavy spray application which may mean crop damage or a poor kill.

To prevent boom whip, provide additional bracing, attach caster wheels, tighten the hitch between the tractor and trailer, or do all three things.

SAFE TRANSPORTATION OF PESTICIDES

Since transportation is expensive, most pesticides are supplied in the compact concentrated form for dilution at the point of application. Where large quantities of concentrated pesticides are being moved, the following points should be taken into account:

1. Many concentrated pesticide solutions contain flammable solvents and care should be taken to keep containers away from source of heat.

2. Since most pesticides are highly toxic and their vapours are equally dangerous, they should not be transported in the same truck as foodstuffs and livestock, even though the containers appear to be sealed.

3. Truck drivers (particularly those handling pesticides regularly) should be instructed as to the hazards of the materials they are carrying, and on emergency procedures in case of an accident. For example:

(a) In case of fire, onlookers and firemen should be warned of the poisonous fumes which are evolved.

(b) Leaky or damaged containers should not be accepted for transportation. Spillages of liquid, or dust, should be treated with sawdust - to absorb excess liquid - and swept into a suitable container for disposal. Sweeping brushes used for cleaning up after pesticide spillages should not be used for other purposes afterwards. After removing the excess of any spilled pesticide, the area should be scrubbed with detergent and water and hosed down if possible.

(c) If fairly large deliveries of pesticides are made regularly, the driver should be provided with a suitable respirator, rubber boots and plastic gloves to be used in cleaning-up operations in the event of spillage. If a spillage occurs in a populated place, the contaminated area should be clearly marked to warn people, and the help of emergency services should be sought. Large scale spillages should not be hosed with water if there is any danger of contaminating a sewage system or other waterway. The excess material should be absorbed on sawdust, lime or sand and disposed of by burning or burial.

STORAGE

The precautions which are necessary for the safe storage of pesticides will be dependent on the quantities and types of compounds being stored.

The following general rules are given as a guide to the precautions which may have to be taken to ensure safety:

1. Pesticides should be stored in cool, well-ventilated rooms and out of the reach of small children. Doors should be locked when the room is not in use.

2. Pesticides should not be stored in rooms which are used as living quarters for humans or animals.

3. Pesticides should not be stored in the same room as food-stuffs for humans or animals.

4. Any room in which larger quantities of pesticides are stored or handled should have notices posted indicating the toxic nature of the materials.

5. Smoking and food consumption should be prohibited in any area where pesticides are stored or handled. Adequate washing facilities with plenty of soap or detergent should be available.

6. All containers should be properly labelled. Poisonous substances should not be dispensed into containers normally holding a food or drink (e.g. pickle jars or 'coke' bottles).

7. Pesticides should not be stored in damaged or leaky containers. Their contents should be transferred to sound containers (wearing suitable protective equipment), and the old containers destroyed.

8. Suitable protective equipment should be available for dealing with major spillages, e.g. respirator, rubber boots, coveralls and plastic gloves.

9. Suitable absorbing materials, such as sawdust or lime, should be available for absorbing spilled liquids, together with brooms, shovels and containers for removal. Buckets, mops and detergents should be available for cleaning up. Brooms, shovels, buckets and containers should never be taken into living quarters after being used for cleaning up pesticides.

10. All spillages of pesticides should be cleaned up immediately.

11. Persons working with pesticides should leave work clothes and boots at their place of work, or in a locked outhouse. After each day's work, the work clothes should be removed, hands and exposed parts of the body should be well washed (a shower would be preferable) with soap or detergent, and clean clothes should be donned. Contaminated work clothes should be laundered regularly, boots should be cleaned and checked for leaks. Badly contaminated clothes should be destroyed.

DISPOSAL

The disposal of waste pesticides and pesticide containers is of great importance to all persons using these materials.

Serious injury could be caused to other people, livestock, crops and wildlife from empty pesticide containers that are left abandoned where they were used, or from excess materials poured away, for example:

(a) Spray tanks that are being drained or flushed out could contaminate the water supply.

(b) Children may play with or even eat some of the soil in an area where highly toxic materials have been poured or thrown out. Waste areas, yards and dumps have a fascination for children who will play with all kinds of junk, including empty pesticide containers, and the dirt in the area where pesticides may have been poured.

(c) Livestock and wildlife may lick contaminated ground, empty containers, etc., and they may drink ditch water contaminated with pesticide waste.

(d) Empty gallon cans, five gallon kegs and other pesticide containers may be used for a variety of purposes, including water storage, if they are not properly disposed of. With hazards such as the foregoing in mind, the following procedures are suggested for pesticide disposal:

1. Empty containers of all types

(a) Make sure the container is completely empty.

(b) Glass containers should be broken and the pieces buried at least 18 inches deep.

(c) Fiber and paper containers should be burned in an isolated place or in an incinerator. Soak the containers with kerosene, light carefully and stay away from fumes and smoke.

(d) Metal containers should be burnt out or washed out and destroyed.

(i) Burning - stand containers close together, open top upwards, in an isolated place. If necessary punch holes in top and sides and soak with kerosene. Cover with combustible material (e.g. wood shavings, paper boxes, firewood) and burn out.
Keep away from fumes and smoke.

(ii) Washing - into the container pour the following mixture:

1 pint water
1 tablespoon of detergent
1 tablespoon caustic soda
(household lye)

for each gallon volume. Thus, a 5 gallon drum will require 5 pints of water, 5 tbsp. detergent and 5 tbsp. lye. (Caution: caustic soda is extremely corrosive to the skin and clothes - follow the precautions given on the package).

Rotate the container carefully until all inner surfaces are thoroughly wet and continue this washing for a few minutes. Pour this solution into a pit at least 18 inches deep in an isolated area away from water supplies. Rinse the container with 1 pint of water for each gallon volume, and discard washings into the pit. Destroy the container by punching holes in it and flattening with a hammer.

2. Pesticide liquids, concentrates and powders

(a) Aqueous solutions - these should be poured into a pit at least 18 inches deep, covered with lime and buried. Disposal should take place at an isolated spot well away from water supplies.

(b) Oil concentrates and dusts, clothes or shavings soaked in pesticides - these may be disposed by burial as in (a) above, or better still by burning. Contaminated rags and other inflammable materials may be burnt in an incinerator. Larger quantities of dusts and liquids should be poured into a shallow pit. This should then be covered with inflammable material such as wood shavings, pieces of wood and paper boxes. The pile is well soaked with kerosene and ignited. Care should be taken to carry out such burning in an isolated place. Ensure that the wind direction is away from any inhabited area and keep well away from the smoke and fumes.

(c) Areas in which pesticides have been disposed by burial should be clearly marked with a painted notice. For example: "DANGER -- POISONS BURIED HERE". Mark the date clearly.

Note: Lime or caustic soda are only effective in neutralizing a few specific pesticides. There are no neutralizing materials for many of the poisonous persistent pesticides - only time, dilution and the effect of air and sunlight may eventually be effective in destroying them.

THE RECOMMENDATIONS GIVEN ABOVE WITH RESPECT TO TRANSPORTATION, STORAGE AND DISPOSAL ARE VERY GENERAL IN VIEW OF THE VARIETY OF PESTICIDES AVAILABLE - IN EACH SPECIFIC CASE THE RECOMMENDATIONS GIVEN IN THE MANUFACTURER'S LITERATURE AND ON THE CONTAINER LABELS SHOULD BE CAREFULLY NOTED.

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July, 1972 J. G. K.